AMER. ZOOL., 24:423–431 (1984)

The Arrogance of Ignorance—Ignoring the Ubiquitous[1]

WILLIAM V. MAYER[2]

Professor Emeritus of Biology, University of Colorado, Boulder, Colorado, and President Emeritus, Biological Sciences Curriculum Study

SYNOPSIS. Anti-evolution, the rise of pseudo sciences, and the renewed interest in the occult, all masquerading as science, are symptomatic of the poor job that is done explicating science as a process and a way of knowing. Disciplinary teaching emphasizes fact over concept. Every science discipline should be taught with a process base pervasive from the first to the last day of the course. Science teaching needs be revamped to provide an integrated, nonredundant exposition of the discipline focussed on principles of which the theory of evolution is only one. Science must to be related both to technology and society. Teaching has to be directed to elicit the desired ends of education and not be regarded simply as a system to deliver fragments of knowledge. The participation of zoologists in delineating the discipline of science and countering pseudo science is essential. Scientists must become involved in science education and participate in updating teachers and insisting on their subject matter competence. University scientists must be concerned beyond the training of majors to provide meaningful education for nonscience majors as well. To ensure quality science education zoologists must become active in resisting incursions of scientific nonsense in science classrooms.

Arrogance comes in a variety of forms. The arrogance of great wealth, the arrogance of great power, the arrogance of great beauty, and the arrogance of a great master are bearable because they rest on an acknowledged and measurable base. The arrogance of ignorance, however, is unbearable because it is rooted in smug satisfaction with being isolated from the facts of the case. The anti-evolution plank in the platform of Christian fundamentalism is a classic example of the arrogance of know-nothings.

Those who remember Mickey Mouse acting as sorcerer's apprentice unleashing powers he could not control will appreciate the situation in which the Biological Sciences Curriculum Study (BSCS) found itself in making the conscious decision once again to introduce the word "evolution" into secondary school biology texts despite the knowledge of potential anti-evolutionist pressures. Prior to 1960 the best selling secondary school biology text did not even have the word evolution in the index and students were exposed to a biology bereft of its most critical unifying principle. H. J. Muller's dictum of "One hundred years without Darwinism are enough" struck a responsive chord when the biology books of America were being analyzed and models prepared for future use. As anticipated, the magic word that BSCS unleashed in 1960 caused the forces of anti-evolution to become reborn with a focal point for their energies.

The anti-evolution movement has grown far more sophisticated than it was at the time of the Scopes trial. With knowledge gained by successive rebuffs it no longer demands that evolution be excluded from textbooks. It has adopted, instead, a philosophy based on the "if you can't lick 'em, join 'em" thesis. Today its members claim not to be anti-evolutionists but, rather, "scientific" creationists who offer an alternative and valid scientific explanation of organismic diversity and relationship. They purport to offer an explanation of origins based on the literal interpretation of the Genesis book of the King James Bible. It is no longer banning of evolution they demand; they plead instead only for equal time and fair play for an alternative, scientific thesis. It is as if Einstein had requested equal time for relativity whenever Newtonian mechanics were to be discussed. The effect, however, is not the same, for the creationist thesis rests on no

[1] From the Symposium on *Science as a Way of Knowing—Evolutionary Biology* presented at the Annual Meeting of the American Society of Zoologists, 27–30 December 1983, at Philadelphia, Pennsylvania.

[2] Address for reprints: 135 76th Street, Boulder, Colorado 80303.

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

valid scientific data, has no hypotheses, offers no experiments, and has no validity within the scientific realm. The demand for its inclusion whenever evolution is discussed has the effect of muting or, worse, permuting the science thus presented. Bad science can not generate valid hypotheses and does nothing to enhance science.

In the beginning, I thought that anti-evolutionists were simply mixed up epistemologically, that they did not understand the structure of knowledge, that they could not differentiate between data derived through a theological system *versus* that derived through a scientific system. I was so naive that I felt logic, reason and the facts of the case would be enough to convince people who were scientifically uninformed. I soon became disabused of the concept that this was an innocent group with which I was dealing. I found, instead, that it was a group whose reception of ideas contrary to their own was blunted by a shield of ignorance proudly borne. This has been demonstrated again in 1983 in relation to the Texas Guidelines and Proclamation 60 dealing with content of texts to be approved for use in Texas. I have testified before the Texas State Board of Education as have distinguished scientists from the University of Texas from Nobel laureates to instructors, citizens concerned with education and churchmen. The Texas State Board of Education, so far, has ignored the ubiquity of scientific evidence and has been refractory to all of this testimony.

While all the sciences support the theory of evolution, the anti-evolutionists ignore such support because they feel obligated to their foreordained conclusions. The Earth must be 10,000 years old; the Noachian flood did lay down the entire fossil record at one time; species are immutable; there is no descent with modification; and organisms are not related. Anti-evolutionists hold such theses in spite of monumental evidence to the contrary. Not only do they display the arrogance of ignorance; they have infinite capacity to ignore the ubiquity of the scientific data that support the theory of evolution.

Regardless of their professed aims their desire is to eliminate evolution, not only from the schools, but from the public mind as well. The lengths to which they will go to achieve these ends is demonstrated by Ray E. Martin in the article entitled "Reviewing and Correcting Encyclopedias." According to Martin the way to deal with the topic of evolution is by ". . . cutting out the sections . . . practical if the portions removed are not thick enough to cause damage to the spine of the book as it is opened and closed in normal use. When the sections needing correction are too thick, paste the pages together being careful not to smear portions of the book not intended for correction." The anti-evolution plea for equal time and fair play is sabotaged by their own actions of which this is just one example. Fundamentalism, with its desire to turn back the clock, has had negative effects on all societies whose policies it has influenced. Paul Gigot writing in the *Wall Street Journal* provides a quote very similar to those heard in the United States to the effect that censors "are hurting our children. They will limit their vision, limit their tolerance." In this case the quote refers to Moslem fundamentalism which is a strong political force in the government of Pakistan.

Science will not alter the mind-set of the anti-evolutionists any more than its data have changed the minds of the members of the Flat Earth Society. Our society can and does tolerate eccentrics; but should not be sympathetic when such as anti-evolutionists organize to convince the general public that their warped data and misinterpretations are based on evidence that is as scientific as that for the theory of evolution. We cannot support in classrooms or in the minds of the general public misrepresented and unsubstantiated statements masquerading as science for, like Gresham's Law in Economics, such poor data, misinterpretations, and muddled epistemology debase the scientific enterprise through confusion and delusion. Science must focus primarily on the uncommitted. Anti-evolutionists cannot be reached. Scientists do not need to be convinced. However, the non-scientific general public is uninformed on the issues and given the fair

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

play, equal time ploy, see no harm in including what they do not recognize as scientific nonsense in science classes.

Why should this be so? The answer is that at all educational levels we usually do an abysmal job of delineating science as a way of knowing. Our students do not understand the validity of data derived through a scientific process compared with that derived through processes of social sciences, the humanities, or theology. They cannot differentiate between a scientific observation and a theological belief. We have given them no guidelines by which the credibility of data in a given situation can be measured. We have students who can define an adambulacral ossicle, but we also have graduate students and, unfortunately, some members of the faculty who cannot define science. If its practioners do not understand the art they practice, how can those who are not conversant with the field be held to understand it?

We are all familiar with the textbook that begins with a chapter on "the scientific method" which goes through a cookbook sequence of truisms that will lead to correct answers if properly applied. Fortunately for the understanding of the scientific process this material is forgotten after the first chapter and never again referred to. We have textbooks at both the collegiate and secondary levels that do not even include the word "theory." It does not seem unreasonable that students in a science course become familiar with such words as data, hypothesis, controlled experiment, theory, induction, deduction, observation, and similar terms that have a quite restricted and specific meaning within the field of science that does not extend to their general use. Time and again I have run across the expression in the general public that a theory is just a random guess. The State of Texas, for example, demands a statement in the front of each secondary biology book that the theory of evolution is "clearly presented as theory rather than fact." The inability to recognize the power of the synthetic explanation of a wide variety of facts that is a theory is understandable when people are not exposed to these interpretations.

It is not enough to simply introduce these terms and define them. They need be used. They need be pervasive throughout a science course. Every new conceptual scheme with which we deal should provide students the critical hypotheses on which it rests. Students should understand the data on which it is based. They should understand the credibility of its statements. We must stop teaching science as packages of facts with which the student can retreat and be assured of truth into the future. The tentative nature of science needs be discussed; otherwise we push students into a dangerous relativism when they find that the facts with which they have been provided are no longer valid. We know that the history of science is strewn with discarded theories which someone at one time held in high repute. We know that our facts change from time to time as we accumulate more information. Science is not dogmatic but forever changing and striving for further explanations of the natural world. That is a noble and contributory undertaking in contrast to the inflexible dogmatism of the anti-evolutionist.

If chemistry and physics and biology are sciences let us teach them as sciences. Let us teach their concepts, their data, their experiments, and their implications for science and society at-large instead of simply presenting formulae and vocabulary to be memorized in incessant sequence while omitting the conceptual base of the discipline. One of the things each of us as scientists should strive for is communicating the nature of the discipline. We have certainly not done very well when you look at the bookshelves in student bookstores and see the tremendous number of pseudo scientific paperbacks passed off as apparently valid science. Von Daniken, Velikovsky, the works of anti-evolutionists, materials on the occult such as the *Amityville Horror,* and other similar volumes, which many take at face value because they have not been given a standard against which to measure such material, all sit on shelves cheek by jowl with science paperbacks. The public has no way of determining that Von Daniken's *Chariots of the Gods* is not equally as valid as the *Double Helix.* They are unable to dis-

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

tinguish between pyramid power and nuclear power. Practically every major newspaper in the United States daily runs a column on astrology, but there is no corresponding column on astronomy even once a month. Among our more popular pseudo scientists are food faddists with their quack diets of black strap molasses and yogurt or other quack health remedies. Some still seek sources of laetrile which has no value whatsoever. People wonder why, if we can put a man on the moon we cannot do something else without realizing that the scientific requirements for putting a man on the moon are quite different than solving societal ills from a social standpoint. Science is poorly understood as a discipline and it makes small effort as a discipline to explicate itself to the general public, let alone its own practitioners.

My first plea, therefore, is to deal with the discipline of science. Deal with science as a process. Make sure that no student taking a science class completes the course without a comprehension of what it is science does, how it is science operates, and the validity of the conclusions reached by scientific mechanisms. Give students an appreciation of science as a standard against which to measure the nonsense pedalled to the public as science.

My second plea is that we go from the general to the specific, integrating our science and avoiding duplication. Currently we present science fractured into a series of independent disciplines to the point where we concentrate on individual trees and the students never see the forest. We speak of the discipline of biology, but we still have many institutions in which students cannot get a degree in the subject. Instead, they take courses in zoology where they learn about the cell, and mitosis and how to use the microscope; they take courses in botany where they learn about the cell, and mitosis and how to use the microscope and they take courses in microbiology where they learn about the cell and amitosis and how to use the microscope. This redundancy, our capacity incessantly to circle a relatively small number of content points at higher and higher vocabulary levels, does much to turn students from science.

Where we developed the concept that first one must have all of the details in place and all of the words defined before one can think properly about a topic I do not know. It is not a procedure we follow in any other field. Politics, for example, seems to demand exactly the opposite set of skills. There is no reason why one could not start with the theory of evolution and, having established its ubiquity, then derive the data on which it rests. Is organismal phylogeny a prerequisite to understanding evolution, or does a comprehension of evolution make organismic phylogeny comprehensible?

Students should be well versed in the big biological ideas and comprehend theories and their applications throughout the field of biology. The germ theory of disease, the chromosome theory of inheritance, and, of course, with primacy above all of these, the theory of evolution—all should be referred to wherever applicable in the course of a year's work and related to and substantiated by the subject matter of a given presentation, whether it be physiological, morphological, genetic, or ecological. Evolution must be the structural element of biology through which all other data become related and explicable. John Moore's essay has given us a guideline when he states "we must accept that everything cannot be covered so the emphasis must be on the ubiquitous and important and not on the rare and important or ubiquitous and unimportant."

We must discontinue teaching science as if it is a self-contained discipline existing of, by, and for itself. Instead we must begin to understand and to communicate the relationships between science, technology, and society. We must acquaint students with the applications of science to their everyday lives. We must refute the image of a scientist as one who makes monsters in the basement or unleashes deadly radiation or chemicals upon an unsuspecting population. Scientists are normally regarded as detached and concerned with other than human issues. In treating science as an enterprise that exists for itself, we have

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

failed to relate science to the human mainstream. Students, particularly non-science students, must become acquainted with the societal applications of science and the fact that scientists are as concerned with society and humanity as anyone. We are always greatly involved with the training of our majors, but a major in science does not present as many problems as a non-major in science. There are more non-majors than majors. Most voters are non-scientists and their misunderstanding of science is abyssal. This is a situation that need be remedied.

In most universities with which I am familiar, the introductory biology program, and particularly if it is for non-majors, is usually assigned to the newest, most junior member of the department who ultimately plans to teach upper division or graduate courses as soon as he can be released from the onerous freshman chore. I submit to you that it should be exactly the opposite. The non-major course should involve the finest minds in the department and should represent a spectrum of science that will impact significantly on those who will take no more science. We cannot wait for a graduate course in evolution to explain evolutionary theory. It must be explained at the introductory level instead of the plethora of useless names and detail that usually occupies the freshman course. There have been some notable exceptions to this observation, but they are too few and far between to ensure that the non-scientists in our colleges and universities have anything like a comprehension of the discipline.

We deprecate the inability of students to read well, to write or to speak well, to think critically, to reason, to analyze, to synthesize, and to evaluate. But why should we be surprised when we do not teach for these ends? Again and again in discussing objectives with educators, I find that their major objective is to create a student who is an independent learner and a rational and critical thinker. But we teach as if dependence were the rule, not independence. We make it impossible for a student to learn outside the classroom. Our programs are geared to criteria which require the student to attend a certain number of classroom lectures, complete certain numbers of classroom examinations, certain numbers of readings, certain numbers of laboratory experiments, and when those are done under our supervision the student then can be pronounced conversant with the topic. Our technique actually prevents the very thing that we declare we wish to do. Basically the bulk of American education in 1980 is similar to the bulk of American education in 1930. We have achieved fifty years of non-progress in education. As a meaningful innovation imagine a university not broken into traditional departments but rather organized around great concepts. A sort of Mortimer Adler's Great Books doing for science what he attempted for all knowledge. What if our teaching programs were ordered around topics such as energy, evolution, development, environment, inheritance and the cell instead of mammalian anatomy, physiology and taxonomy? The prospect for new syntheses and conceptual learning would be greatly enhanced.

It should not come as any shock that we are a scientifically illiterate society. Half of the population makes its acquaintance with science in the elementary and secondary schools and most of the other half receives a quick survey in an introductory collegiate course. It is these courses on which we need to concentrate to alleviate the scientific ignorance of our population and it would not, incidentally, hurt to have those who major in science understand more about it as a discipline and as a way of knowing. The arrogance of ignorance is everywhere apparent. Decisions are being made loudly and clearly on inadequate and inaccurate data. The proponents of certain theses seem almost proud of the fact that they are not influenced by the realities of the situation. When all around us we can see the necessity for scientific knowledge and for a comprehension of the relationship between science, society and technology we seem to be offering less and less in the way of such comprehension. We are ignoring the ubiquitous. We speak of an age of sci-

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

ence, we speak of an age of technology, we speak of necessity of a scientifically and technologically literate population and we ignore the evidence that we seem to be proceeding to exactly the opposite end.

My third plea is for the scientific community to participate more actively in countering the attacks of the know-nothings of the world and to become involved in science education at all levels. The scientific community *must* organize resistance to those who wish to remove something from a curriculum, place something in a curriculum, or change something already in a curriculum to reflect their own personal, special, non-scientific interests. This means that scientists must speak out against the anti-evolutionists, those who do not believe in the germ theory of disease, the anti-sex educationists, the anti-behaviorists, the anti-vivisectionists, those against population control, and others with special axes to grind and who want the data of science changed to reflect their personal biases.

Twenty years ago I found it very difficult to enlist the services of my scientific colleagues to counter anti-evolutionists. Most responded to my importunings with only two kinds of reaction. One was apathy. They simply did not see how anti-evolution would in any way influence their own researches or their own scientific interests. The other was incredulity. Certainly I was mistaken that a tempest was abrewing in a teapot. No thinking individual could return to the Wilberforce/Huxley era and certainly none in this enlightened age could give credence to either the immutability of species or a young earth. However, this situation has changed as the scientific community has observed the successes achieved by the anti-evolution movement through default. The fact that a state legislature would actually pass a bill giving the Genesis version of the King James Bible equal classroom time with the theory of evolution did cause some reaction within the scientific community. Practically every major scientific and educational organization in the United States is now on record as opposing the teaching of creationism as science whenever evolution is mentioned, but it is not sufficient that resolutions be passed. They are helpful, but they are like the studies that clog my files. Without active implementation they are conveniently put away and forgotten.

I also speak for active involvement of professional scientists in the field of education, and certainly within the field of science education. A couple of years ago the topic of creationism was brought up in the schools of Livermore, California. Now Livermore, as you know, is an area of high scientific technology. The Livermore Laboratories are there and there is a population of scientists and engineers who are supposedly concerned with parameters of their discipline and the scientific education of the youth of the community. It was the mothers, however, who uncovered the problem and led the fight. A pupil came home from the Livermore public schools and asked his mother if the family believed in evolution, to which his mother replied in the affirmative. The child then responded, "Well then, we can't believe in God, can we?" Investigating where this statement came from led to uncovering the fact that creationism was being taught in a public school and that students were being told that one either believed in God or atheistic evolution; but could not possibly believe in both. It was the mothers of the region who led the fight to remove this dogma from the public schools of Livermore. If this type of thing can happen in a high-technology scientifically oriented community, think of its impact in areas less sophisticated in scientific matters.

The history of American science education is one of lurching from crisis to catastrophe. In the late 1950s the Soviet Union did American education a great favor by launching Sputnik before our own space efforts were off the ground. It is not quite fair, however, to indicate that the entire educational reform movement of the 60s was a direct result of the Soviet's Sputnik. Prior to that time there had been periodic concerns about the quality of American education in science and mathematics and some curriculum reform projects were underway. Sputnik may have accelerated this concern but already in pre-Sputnik

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

days, work was being done to alleviate it. I use "work" in the sense of something being actually accomplished. Mostly we study a problem to death. I have filing cabinets full of studies which reiterate the same theses over time. In 1960 Paul DeHart Hurd published a book entitled *Biological Education in American Secondary Schools—1890–1960* which demonstrated that there was nothing new under the sun. Commissions and study groups since 1890 had been meeting and making recommendations that were simply not implemented. Today, in 1983, we are still producing reports about the state of education in the United States with no plans for implementation of their recommendations.

The one golden moment in American education that resulted in action not words was the curriculum development movement of the late 1950s and early 1960s. Funds were made available through the National Science Foundation to groups of scientists and educators to revise secondary school curricula to bring them in line with the cutting edge of disciplinary knowledge. The CHEM study, the Chemical Bond Approach, PSSC physics, and a variety of mathematics programs, in addition to the programs of the Biological Sciences Curriculum Study, resulted in books that have had a lasting impact on secondary science education. The products of these studies were not intended as an end in themselves but simply as models of what should be, and it can be said without fear of contradiction, that no secondary science book in the 1980s has been uninfluenced by the work of these curriculum groups.

However, today, in 1983, we face another crisis in science education. Were the curriculum development activities of the 1960s a failure? The answer is "No." They were a step in the right direction but they dealt basically with one facet of science education, namely textbooks which they dragged kicking and screaming into the 20th Century. However, this effort can be likened to running a 90-yard dash—an event for which no award is given. Concurrently with the appearance of new textbooks, the National Science Foundation undertook what was initially a program to up-grade teachers of science who had not returned to the classroom for a decade or more. However, there was little coordination between the curriculum materials produced and the teacher preparation activities that ensued. As a matter of fact, NSF went out of its way to avoid promoting what it regarded as its own wares. The result was that one branch of NSF put money into the preparation of new science materials while another branch prepared teachers, but not necessarily in the NSF sponsored curriculum materials.

The educational establishment is a complex of interactions among textbooks, teacher preparation, colleges of education, standardized examinations and the multiplicity of school districts in the United States, each with its own objectives and each with its own priorities. Paul Hurd has compared education to a multi-billion dollar corporation with 17,000 Boards of Directors. The argument between centralized *versus* diversified control of schools is one that has involved every segment of our society with proponents on both sides pleading on the one hand for unity, on the other hand for diversity. Intelligently handled either option can lead to successful educational practices. Without intelligent leadership neither is worth considering. Unfortunately, mismanagement in either system has usually been interpreted as a deficiency of the system itself rather than a problem of placing blame where blame is due. Frequently the representatives of various segments of the educational continuum blame one another for lack of progress. We have a vertical column of blame. The graduate schools indicate that the undergraduate program does not properly prepare students for graduate work. The upper division of a college or university blames the lower division for the lack of preparation of its students. Those in charge of freshman courses blame their lack of success on the secondary schools. And then, in turn, the blame cascades down to junior high schools and elementary schools and kindergarten and preschools. None of which, apparently, is doing the proper job of educating for those more elevated in the hierarchy.

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

In addition, there is a horizontal plateau of blame. The teachers blame the parents and the home environment. The parents, in turn, put the blame at the door of the teachers. The textbook becomes a matter of controversy. If we had better and more modern texts, we could do a better job; or the textbooks we have incorporate values that are better dealt with in the home environment. Teachers blame administrators; administrators blame teachers. Colleges of education, when called to account for the quality of their graduates, blame their problems on the liberal arts colleges. They say, in essence, that their students get their subject matter backgrounds from colleges of liberal arts and that education colleges really have them for a very short period of time, so they cannot be blamed for their lack of ability. However, no concerted effort has been undertaken to prepare teachers properly in subject matter. Most subject matter departments make no concession to the tasks of the teacher, and most courses are not applicable to the problems with which the teacher will have to deal. How many introductory biology courses, for example, devote any significant time to the theory of evolution and its place within biology? How many biology majors have ever had a course in evolution? How many universities even offer such a course? The training of teachers is done poorly. Colleges of education devote little time to subject matter, but instead, concentrate on what they term the art of pedagogy.

All kinds of requirements have superceded classroom competence. Unionized school districts allow seniority to be a governing factor in retention and promotion. A superior science teacher with 10 years of service might find his place taken by a home economics teacher with 15 years of service. These lateral arabesques do education no good and place teachers not competent to deal with the content of the discipline under consideration in front of classes. Actually, the number of teachers properly certificated to deal with science is far less than 100% and growing smaller all the time. Today, an art teacher may be handling sections in science. Until we are capable of placing properly prepared teachers in science classrooms, science teaching will suffer. With many collegiate departments being reduced in size or eliminated entirely, there has been a move at the college level to perform similar lateral arabesques with the thesis being that a person with a Ph.D. in a subject matter should be able to transfer laterally into another field because of innate competence in knowledge and the art of teaching. So far this has not gotten very far in the university system although some junior colleges and some small colleges have transferred professorial personnel across the disciplines. It seems odd that in the field of higher education where teaching competence has not normally been a criterion for hiring, retention, or promotion, that one would be able to make the case that there is a teaching art transferrable from one discipline to the other.

Our educational system is frequently a placebo system. We avoid controversial issues simply because they lead to contention. But education demands we deal with controversial topics; not indoctrination, but education. The line is thin, but it can be walked. To avoid the teaching of evolution because it induces problems is to avoid educational responsibility. Evolution is the warp and woof of biology as the atomic theory is for chemistry. Biology no more makes sense without the unifying conceptual scheme of evolution than the elements could be ordered without an understanding of atomic theory. The implications of evolution for human welfare and undertakings is well documented in the accompanying essay of John Moore (1984). Teachers in the public schools are particularly intimidated by the teaching of evolution for the anti-evolutionists have been active on the local front. They spend their time dealing with all facets of the educational continuum; they importune legislatures for equal time laws, which is perhaps their least successful activity but one that is highly visible and garners them the publicity they so need for continuing fund appeals. They have had better success with state boards of education. The Texas Board of Education, for example, has bought the

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

anti-evolutionist arguments lock, stock, and barrel while, at the same time, disclaiming that any anti-evolutionist input has been involved. The intellectual gymnastics required to implement anti-evolutionist dogma while denying that it has any influence on the actions taken is a wonderful sight to behold at a Board of Education meeting.

The anti-evolutionists importune school administrators, local school boards, and individual teachers to eliminate, mute, or misrepresent evolutionary theory or to turn science classes into Sunday School classes by the demand that Genesis be given equal billing whenever the theory of evolution is mentioned. Teachers who have a hundred and fifty students a day in five different classes are not looking for further divisive activities of a contentious nature. When badgered by anti-evolutionists they normally capitulate. They solve their problem by falling completely into the anti-evolutionary trap by simply not teaching evolution. This way they avoid the possibility of extended contentious confrontations. As evolution was never a major part of their biological coverage in the first place, they feel its elimination is no great loss and a small price to pay for community peace and quiet. Thus, the anti-evolutionists, by simply threatening to demand hearings or bring legal actions, force the elimination of evolution from the curriculum without a shot being fired. Not every teacher wants to be a John Scopes. They have neither the heart nor the mind for the task.

In summary, what we need is sustained federal interest in quality education. We need updated, non-redundant curricula that reflect the current state of the discipline and integrate it with other disciplines as well as the daily lives of our students. We need teacher education programs that will update those teachers who have not had a class in science for a decade or so. We need colleges of education that ensure subject matter competence for teachers as well as pedagogical competence. We need a coordinated effort to improve the quality of science instruction. To this end we need untainted textbooks—ones that present the conceptual basis of the discipline without bias. We need the processes of science to pervade both our books and our classes. We need to eliminate the practice of placing non-qualified teachers in front of classes simply because of their longevity within a given system. If teachers are to make lateral arabesques in their career this should not be done until they have had a chance to be prepared in the subject they are asked to teach.

And lastly, we need the cooperation and involvement of the entire scientific community to take a stand for quality education and to resist the incursions of non-scientific nonsense masquerading as science. We cannot tolerate the arrogance of ignorance nor ignore the ubiquity of scientific concepts in our daily lives. We must all strive for the achievement of scientific literacy. It is the job of each and every one of us to insist that science education is modern, accurate, and comprehensible and to ensure that, while there may be non-science majors, there are none who remain unacquainted with untainted science.

REFERENCES

Anson, J. 1978. *The Amityville horror.* Bantam Books, New York.

Gigot, P. A. 1983. Moslems in turmoil. Wall Street Journal. 109:1 and 16.

Hurd, P. deH. 1961. *Biological education in American secondary schools 1890–1960* BSCS, Colorado Springs, CO.

Martin, R. E. 1983. Reviewing and correcting encyclopedias. Christian School Builder 15:205–207.

Moore, J. A. 1984. Science as a way of knowing—Evolutionary biology. Amer. Zool. 24:467–534.

Muller, H. J. 1959. One hundred years without Darwinism are enough. Sch. Sci. and Math. April: 304–316.

Texas State Board of Education. 1983. The Texas textbook proclamation. 1. Textbook content-general sect 1.3(1)

Velikovsky, I. 1950. *Worlds in collision* Pocket Books, New York.

Von Daniken, E. 1971. *Chariots of the gods?* Bantam Books, New York.

Watson, J. 1968. *Double helix* Mentor Books, New York.

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

obviously far from a conclusive answer. It is also true that the scientific advances, in recent years, have occurred so rapidly that most people cannot digest the rush of new discoveries. The brisk output of new knowledge disturbs one's serenity. Indeed, the novel and awesome powers of modern science arouse suspicious concern. The real hazards of nuclear power and the greatly magnified risks of recombinant DNA research have tended to undermine public confidence in science. To many people, science has become a dehumanizing force in our society. It may well be that many people are rebelling not so much against science as against a world they perceive as insensitive to human values. Such rebellion may be part of a broader anti-intellectualism. Nevertheless, our universities must assume a prominent role in countervailing, or at least neutralizing, the antiscience attitude.

Tragically, the greatest culpability for the sad state of society's scientific understanding is our educational system itself. Education in the sciences is pathetically wanting. Too many students leave our lecture halls unable to reflect thoughtfully on scientific information. Yet our students will shortly find themselves within that segment of society whose views are most influential in shaping public response to scientific developments. It is important that our students be prepared to evaluate evidence dispassionately. Why is science education in such sorry shape? Some of the reasons will become apparent as we explore another recent episode.

An incredulous story unfolded in Louisiana in the summer months of 1981. For several hectic days in mid-July, educators, scientists, and thoughtful theologians earnestly entreated Governor Treen to veto a misguided bill, which mandated that the public schools of Lousiana teach the so-called theory of "scientific creationism" whenever Darwinian evolution is taught. But the voices of scholars fell on deaf ears. Scientific creationism is a perversion of both science and religion. University scientists have been justifiably perturbed by the irresponsible distortions of science habitually propagated by fundamentalist creationists. Biblical scholars have been embarrassed that religious beliefs are misrepresented by the creationists as true science. As one prudent theologian stated, the theory that God made a young earth (not more than 10,000 years old!) to look old (that is, instant antiquity!) invites the deplorable idea that God cannot be trusted.

The roots of the creationism movement spring from Protestant fundamentalism and political conservatism. The legislators and Governor Treen capitulated to the intransigent Protestant fundamentalists, who insist on the literal truth of the Bible and have a strong following in north Louisiana. The measure was authored by Senator William Keith, a Baptist divinity school graduate, who publicly stated his indignation that his children were taught that "they came from monkeys." To the creationist, any notion that humans evolved from lower forms of life is unconscionable because of the biblical account of God's special creation of Adam and Eve. To a biologist, it is utterly incomprehensible that students leaving our educational system can remain naive enough to believe that a rib from a man can be used to create a woman, or that the universe is no more than 10,000 years old. Certainly, there is a major failing in science education if our students are unable to differentiate between religious beliefs based on inflexible propositions and scientific concepts grounded in testable hypotheses. Fundamentalist creationism is not a scientific alternative to Darwinian evolution. Scientific creationism demands the absolute acceptance of views not subject to test or revision. Science necessarily rejects certainty and predicates acceptance of a concept on objective testing and the possibility of continual revision. The claims of the creationists are unverifiable (or unfalsifiable) and, hence, inherently unscientific.

The reaction of the public to the issues of scientific creationism has been largely one of confusion. The average person in the street has been baffled by the complex arguments on both sides. Creationists challenge the validity of the data supporting gradual evolutionary change, emphasizing the deficiencies in the fossil record. Evo-

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

lutionists acknowledge that there are uncertainties in the details of evolutionary history, but that our body of evolutionary knowledge is continually growing and increasing in accuracy. The layperson is not generally conversant with the philosophy or methodology of science and lacks the confidence to weigh the issues. The local citizen perceives the controversy as a dispute between two groups of passionately committed individuals and supposes that one outlook is as good as another. When the creationists ask for equal time in the science classroom, the person in the street views the situation as a reasonable request for fair play. This would not be disconcerting, were it not for the fact that local citizens do impact upon our educational system in many ways. Local citizens serve on boards of education, and are dragged into textbook disputes—including the rejection of texts that propound the evolutionary concept. Accordingly, our local citizens are important because their views are heard or expressed in parents' groups, board meetings, and referendums.

A major complaint of professors at colleges and universities today is that entering freshmen are uneducated, if not practically illiterate. The teaching of science to disinterested, unsophisticated students is a difficult endeavor. Beginning students enter college with vague and naive notions about evolution. They look upon evolution as something that has occurred in the remote past. They know it has something to do with dinosaurs, rocks, and the proverbial "missing link." And they are familiar with such proverbial cliches as "struggle for existence" and "survival of the fittest." But, even after a year of introductory college biology (or because of such exposure!), the average student is still disbelieving that the human species is simply an incidental and fortuitous episode in the age-long history of life. Students may acknowledge that the story of Adam and Eve is a myth, but Darwinian evolution represents a crushing blow to their preening self-esteem. It is inconceivable to many students that humans are not the unique crown of the universe. Science demeans the concern for our ultimate destiny. If we are simply an animal, how could we have an immortal soul, destined for eternal happiness (or punishment)? Many students make a point of being religious in order to avoid the fires of Hell or reincarnation in some less desirable form.

Darwinian evolution ostensibly robs human life of its mystery and melancholy. One of the most painful disappointments to the poetic or romantic mind is acceptance of the notion that life may not be eternal. A prevailing feeling is that science squeezes the beauty and warmth out of all that it touches. The remarkable advances wrought by science and technology are viewed as satisfying only our material needs—from the harnessing of steam and electricity to the development of antibiotics and vaccines. Very rarely are the achievements of science thought of as enabling men and women to have a more humane view of their fellow passengers.

Darwinian evolution does offer a new way of looking at nature and a new way of looking at life. Yet, our college students have not appreciated the potentially profound implications of Darwinism for developing a comprehensive view of human nature. The students, however, have assimilated the precepts of art, music, literature, and philosophy—all of which have strong elements of religious intuition or of mystic communion. The humanities—not the sciences—make students feel more humane. The humanities are the disciplines that express concern for the human individual.

The college freshman stands with one foot in the twentieth century and the other in the thirteenth century. The resultant straddle between science and superstition is both painful and embarrassing. Some students attempt a reconciliation or fusion of the two ideologies: naturalistic and mystic. For many students, the mystic conviction is overwhelming and primary, overriding any consideration of objective science. In fact, students are drawn to the occult, the supernatural, and the paranormal. It is as if they crave to learn the secrets of their "psychic souls." The students delve into movies, books, magazines, and cassettes dealing with subjects ranging from astrology to witchcraft. Occultism has been promoted by the popular media. Even

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

though occult or illusory beliefs are objectively unsupportable, many students uncritically endorse the fanciful. Apparently, the need to retain irrational beliefs satisfies personal needs that seem to be denied by modern science and technology.

There is an important lesson to be learned: Science, evidently, is not viewed by students as a way of reaching a deeper understanding of ourselves or of our environment. Science, unlike the occult, is not apprehended intuitively by the students. Science is, at best, a dry technical methodology, with its antiseptic habits of close analysis. It is cold and impersonal. The study of science is alienated from the life of the student. The agonizing feature of science education today is the wide gulf between one's studies and one's life. The challenge of education in the sciences is to expose students to learning experiences that will make the scientific outlook part of their daily living. The challenge is to offer the student a curriculum in which learning and living can be integrated. The student must experience learning. Changes in skills and judgment occur when the student lives through an event or events.

The insensitivity or indifference of the students to science reflects our traditional curriculum with its emphasis on passive learning. The student's traditional role is that of a passive note-taker and regurgitator of bits of facts. From kindergarten on, students have been exposed to a model of learning in which the teacher decides what information the student should learn, how it is to be learned, in what sequence, and at what pace. The paramount feature that identifies a teacher-centered curriculum is that the student is not responsible for his or her own education. The student's task is to copy a steady stream of words in a formal lecture and to repeat the information parrot-like on command. The students are so preoccupied with transcribing the gospel-like offerings of a lecture that they scarcely have time to ask questions. The rewards to the student in a teacher-centered curriculum are usually external, as motivation is based primarily on grades and not on a personal desire for achievement.

Let us consider the full implications of a teacher-centered curriculum. The vast bulk of students who will take freshmen college biology—fully seven-eighths of them—will never enter the door of a biology classroom again. Yet, all too often the liberal arts nonscience major is exposed to a highly factual, encyclopedic introductory course in biology. The course is frequently an introduction to advanced courses for the science major that the nonscience student will never take. Rarely does the student experience the intellectual excitement involved in the search for knowledge, or sense the fervor in scientific inquiry. Lost in the lecture process is any participatory probing by the students. The passive role of the student contrasts sharply with the active role of the teacher. The teacher's activity promotes learning—for the teacher, not for the student! By and large, the teacher feeds information to the students as a finished product, and does not reveal his or her own creative efforts in weaving the material in finished form. Teachers feed students complete meals, to borrow an analogy from Robert Marcus, provost of Rollins College. The teacher does not generally invite the students into the kitchen to witness all the crucial ingredients and manifold steps used to prepare the final fare presented to the students in the dining room (or classroom). We should be able to devise an instructional program around the precept that we make available to our students the skills in learning that we possess but which the students have not yet acquired.

Evaluation procedures are necessary to assess student progress and competence. Unhappily, evaluation is usually accomplished by the wrong approach: stereotyped, standardized, non-educational examinations. For students, past schooling has equated education with objective-type examinations, and the colleges reinforce that view. Faculty members remain complacent in their ignorance of the pitfalls of standardized examinations and the students suffer. A standardized examination of a multiple-choice format usually places stress on simple recall of information. It is safe to say that objective-type examinations

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

do not properly test competence in the sciences. Multiple-choice-type examinations glorify facts; indeed, only an expert in the given speciality can answer many of the trivial questions. Most knowledgeable educators contend that a standardized examination measures only how well a student has studied for the examination.

We may well ask: Are there any redeeming features in a teacher-centered curriculum? Presumably a primary goal in a teacher-centered curriculum is to transmit an organized body of knowledge. It is assumed that when a student has amassed a large body of knowledge, he or she is prepared to apply that knowledge to the solution of problems in everyday life. Ironically, the student is given a problem to solve after he or she has been provided with the facts. But this is contrary to what occurs in real life. In our daily lives, we face many problems, and learning occurs as we work toward an understanding or resolution of the problem. Thus, in the daily learning process, the problem is encountered first. In the education of our students, should not the problem be given to the student first?

The use of problem-based learning provides a rich vehicle for making our students active participants in the learning process. It is fruitless to have a vast store of information without a method of ordering the information. The body of factual knowledge in science becomes meaningful when it is used in the solution of a problem. Students acquire knowledge in relation to the resolution of problems. The assumption of sequential learning is challenged by the problem-solving approach. In evolutionary biology, for example, it is not necessary to learn the evidences of evolution before one can tackle a problem concerned with the mechanism of evolution.

In problem-based learning, the student is presented with an unknown problem. He or she must seek out the relevant information, formulate a hypothesis consistent with the observations, deduce predictions from the hypothesis, and subsequently accept, reject, or modify the hypothesis in accordance with the degree of fulfillment of the predictions. This model of learning has been variously defined as problem solving, critical thinking, reflective thinking, discovery, and inquiry. The mode of inquiry is the hypothetico-deductive style of reasoning that is the cornerstone of investigative science. Learning by this method has an important educational objective: the development of the habit of scientific thinking, characterized by objectivity, open-mindedness, skepticism, and the willingness to suspend judgment if there is insufficient evidence. It has been my experience that students, when given the opportunity, generate hypotheses quite naturally. Indeed, the practical problem is often one not so much of uncovering hypotheses as of holding them in check. As Charles Darwin once remarked, students have to learn to be wary of emotional commitments to their cherished hypotheses. Darwin wrote in his *Autobiography*: "I have steadily endeavoured to keep my mind free so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject), as soon as facts are shown to be opposed to it. Indeed, I have had no choice but to act in this manner . . ." (Vol. 1, pp. 103–104. F. Darwin (ed.). 1888. *The life and letters of Charles Darwin.* 3 vols. John Murray, London).

One of the most effectual ways of implementing problem-based learning is to organize the students in small discussion groups. The potential of learning groups in higher education has yet to be realized. One could argue effectively that group learning should be the principal, even the exclusive, process in a college course, and not a supplement to the usual lecture method. To ensure active participation by all members, learning groups are kept small—about 5 to 6 members. The student brings to the problem all of his or her previous educational experiences. The members of the group learn with and from each other, benefiting from their diverse backgrounds. The group develops a sense of responsibility for the learning progress of each member, and the students learn how to give accurate and candid feedback to each other. The process is often difficult because it represents a stark contrast to the previous competitive educational system to

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

which most students have been exposed. The tone of the group should be open and gentle; the attitude should be cooperative and mutually reinforcing. The personal interactions typically highlight strengths, weaknesses, and prejudices of the students, enlarging their view of themselves and enlarging their capacity to be open-minded, if not critical-minded.

Although the faculty member in charge of the small group is an expert or specialist in some branch of science, his or her role is primarily that of a generalist and a facilitator. The faculty member (often referred to as a tutor) must have the skills necessary to guide and facilitate discussion, as well as to design and assemble problem-based learning materials. The learning resources involve a variety of audio-visual techniques and educational approaches that include programmed learning. The tutor encourages and stimulates the discussion but does not direct or dominate the group. The initiative for learning remains in the hands of the students. The procedures are not open-ended, nor are the discussions free-wheeling. The group sessions are carefully planned, with explicit goals and activities.

The learning group is generally assigned one problem per week, and two or three sessions spread over the week are devoted to the problem. In evolutionary biology, each problem is designed to aid the student's understanding of a particular facet of evolution. As seen in *Appendix A,* one of the simplest, albeit instructive, problems involves the emergence and predominance in modern times of dark (or melanic) varieties of moths in the industrial areas of England and continental Europe. The problem is of particular interest because it represents a situation in nature in which an evolutionary change is not only observable but rapid as well. In the initial assessment of the problem at the first session, the students in the group identify the relevant components: smoke-polluted industrial regions, protective coloration, predatory birds (presumably insect-eating), and a host of other concerns. Once the dimensions of the problem are defined, the students discuss the observations and entertain a range of feasible hypotheses. If their knowledge is inadequate to immediately test certain hypotheses, the task becomes one of seeking out information in the library from textbooks and audio-visual presentations. Accordingly, the first session generally concludes with a discussion of the kinds of information that would appear to be necessary for the solution of the problem.

The second meeting of the group typically involves the application of the newly acquired data to the problem. The group members discuss how the new observations support some hypotheses and refute others. The group reviews all information and synthesizes a coherent explanation for the phenomenon being investigated. There inevitably arise questions of a general nature that warrant exploration and discussion. Examples of such questions might be: How do mutations arise? Is there a mathematical model for the process of directional selection? Can a deleterious recessive mutant gene be completely eradicated in a natural population by the severest form of selection? Extended discussions of such probing queries would provide for an instructive third group meeting during the week.

A more complicated problem, described in *Appendix B,* involves the emergence of multiple-resistant strains of bacteria to antibiotics. Several simultaneous mutations from sensitivity to resistance are usually hypothesized by students, but the emergence simultaneously of four or five different mutations to several different antibiotics must be viewed as highly improbable. The problem becomes particularly challenging as it involves facets of which most students are completely unaware, notably the phenomenon of the formation and exchange between bacteria of special episomes that carry several "resistance" loci. It has been observed that students learn best when researching a problem that is exceptionally challenging.

The development of intellectual skills beyond memorization and recall is generally a slow, frustrating process. Admittedly, progress in developing critical think-

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

ing skills is difficult to measure. Evaluation typically takes the form of written problems, in which the students are required to write out in detail their arguments for proposing one or more interpretations. The examination problems are of comparable difficulty to the problems explored in the group sessions. Several provocative essay-type questions are posed for a given problem. A sample examination problem appears in *Appendix C.*

For both student and teacher, the learning groups are stimulating and vigorous. It is my personal view that the basic philosophy and method are right, although a program of group learning is difficult to implement, particularly with massive numbers of entering students in large universities. I expect to be told that this remedy for science education is hopelessly impractical, but this does not deter me. Our present system of undergraduate education in the sciences is futile—it is too authoritarian, too inclined toward passive learning, too detached from the students' ongoing lives, and too impersonal. What is urgently needed is an educational program in which the students become interested in actively knowing, rather than passively believing. The students should be allowed to learn, not forced to learn.

When I first started teaching, I entertained the prospect that human conduct could be guided through knowledge and reason. If we could learn to make decisions based primarily, if not solely, on empirical evidence, we would be able to manage constructively our own destiny and construct a good, or better, society. In essence, through the habit of scientific thinking, we would develop rational insight. And, rational insight or intellectual self-awareness hopefully would reach a sufficient point to enable us to become free of irrational determinants.

Today I am less sanguine about eliminating the irrational determinants. I am now more interested in the skills of interpretation that the student possesses. I am content that the student develops the critical skills that enable him or her to distinguish between occult beliefs and objective knowledge. It may be too much to expect the average student to reject as false or invalid all ideas that are in conflict with empirical data. I do expect, however, that the students develop an attitude in which the concepts of science, particularly as they relate to evolution, are received in an open-minded manner, and given impartial consideration.

APPENDIX A

PROBLEM 1
INDUSTRIAL MELANISM

Slightly more than a century ago, dark-colored moths were exceptional in rural areas of England. The typical moth in the early 1800s had a light color pattern, which blended with the light coloration of tree trunks on which the moths alighted. But then the industrial revolution intervened to materially alter the character of the countryside. As soot and other industrial wastes poured over rural areas, the vegetation became increasingly coated and darkened by black smoke particles. In areas heavily contaminated with soot, the formerly abundant light-colored moths have been supplanted by the darker varieties. This dramatic change in the coloration of moths has been termed "industrial melanism." During the past two decades, several scientists, particularly E. B. Ford and H. B. D. Kettlewell at the University of Oxford, have analyzed the phenomenon of industrial melanism.

In the 1950s, the British Parliament passed the Clean Air Act, which decreed, among other things, that factories must switch from soft high-sulfur (sooty) coal to less smoky fuels. The enforcement of this enlightened smoke-abatement law has led to a marked reduction in the amount of soot in the atmosphere. In the 1970s, the University of Manchester biologist L. M. Cook and his colleagues reported a small, but significant, increase in the frequency of the light-colored peppered moth in the Manchester area.

Consider the issues. Provide plausible explanations for the phenomenon of industrial melanism.

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

APPENDIX B

PROBLEM 2
BACTERIAL RESISTANCE TO ANTIBIOTICS

In 1955, a Japanese woman who recently returned from Hong Kong developed a severe case of intestinal dysentery, which failed to respond to treatment with a variety of antibiotics. When the causative agent was isolated, it turned out to be a typical dysentery bacillus of the genus *Shigella.* This bacillus, however, happened to be very unusual. It proved to be resistant to four drugs, sulfanilamide and the antibiotics streptomycin, chloramphenicol and tetracycline. In the next few years the incidence of multiple drug-resistant dysentery in Japan increased. In fact, there have been a number of epidemics of intractable dysentery.

During a single outbreak of the disease on one occasion, resistant bacilli were isolated in some patients and sensitive bacilli of exactly the same type were isolated from other patients. Even the same patient may yield both sensitive and resistant shigallae. Moreover, the administration of a single drug (say, chloramphenicol) to patients harboring the sensitive organism may cause them to excrete bacteria that were resistant to all four drugs. It was then found that many of the patients who harbored drug-resistant shigellae also harbored strains of the relatively harmless colon bacillus *Escherichia coli.* The latter bacteria were also resistant to the four drugs.

Consider the issues. How can multiple resistance to drugs arise and be perpetuated in a given bacterial strain?

APPENDIX C

EXAMINATION 1
AUSTRALIAN RABBIT

The European wild rabbit has gained infamous notoriety in Australia as the most serious economic pest ever introduced on this isolated island continent. In 1858, a small colony of 24 wild rabbits was brought from Europe to the state of Victoria in the southeast corner of Australia. From such modest beginnings, the rabbits multiplied enormously and by 1928 had spread over the greater part of the Australian continent. Estimates placed the number of adult rabbits at over 500 million in an area of about 1 million square miles. In overrunning the open grassy plains, the rabbits caused extensive deterioration to sheep-grazing pastures and to wheat fields.

For many years the Australian government spent large sums of money on various measures to control the population explosion of these prolific rabbits. Trapping, rabbit-proof fencing, poisoning of water holes, and fumigation all proved to be largely ineffectual. Then, beginning in 1950, outstanding success in reducing the rabbit population was achieved by inoculating rabbits with a virus that causes the fatal disease *myxomatosis.* The deadly myxoma virus was implanted into the tissues of rabbits in the southern area of Australia. In a remarkably short period of time, the virus had made its way, aided by insect carriers, into most of the rabbit-infested areas of the continent. By 1953, more than 95 percent of the rabbit population in Australia had been annihilated.

However, after their drastic decline in the early 1950s, the rabbit populations begin to build up again. Moreover, the viruses in the rabbit hosts were found to be less virulent than they had been initially.

QUESTIONS

1. Provide an explanation for the emergence of less virulent strains of the myxoma virus in present-day rabbits of Australia.
2. Account for the fact that present-day rabbits in Australia show less severe manifestations of the formerly fatal myxomatosis.
3. Explain how evolutionary mechanisms play a role in the acquisition of host resistance to infectious disease.
4. Based on a variety of serological tests, the myxoma virus from North America differs appreciably in its infective properties from the myxoma virus of Australia. Predict the outcome of inoculating present-day rabbits of Australia with the North American strain of myxoma virus.
5. What has been the impact of repeated

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

past epidemics of tuberculosis and bubonic plague on the relative resistance of modern Europeans to these infectious diseases?

6. A virus depends entirely on the living host cell to provide the biochemical machinery and energy for its own replication. Explain how a virus takes over control of the protein-synthesizing capacities of the host cell and directs the apparatus toward synthesis of its own peculiar proteins.

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024

Downloaded from https://academic.oup.com/icb/article/24/2/423/2018453 by guest on 12 September 2024